AN ASSESSMENT OF NON-INDIGENOUS FISH FROM TEMENGOR AND CHENDEROH RESERVOIRS IN MALAYSIA

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AN ASSESSMENT OF NON-INDIGENOUS FISH FROM TEMENGOR AND CHENDEROH RESERVOIRS IN MALAYSIA

by

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Read! In the name of thy Lord Who created.

Created man out of a clot of congealed blood…

Proclaim! And thy Lord is Most Bountiful,

He Who taught by the Pen…

Taught man which he knew not.

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LIST OF SYMBOLS AND ABBREVIATION

%	Percentage
°C	Degree celceous
µS	Micro Siemens
‰	Permil
ABRC	Analytical Biochemistry Research Centre
ANOVA	Analysis of Variance
b	Growth coefficient
C	Carbon
Ch	Chenderoh Reservoir
CI	Confidence interval
cm	Centimeter
df	Degree of freedom
DO	Dissolved Oxygen
ED	Early detection
FOC	Frequency of occurance
g	Gram
GIS	Geographical Information System
GL	Gut length
GPS	Global Positioning System
GSI	Gastro somatic index
GW	Gut weight
IAS	Invasive alien species
IRI	Index of relative importance
IS	Indigenous species
K	Growth constant
Kn	Relative condition factor
L	Litre
LR	Locally rare
LWR	Length-Weight Relationship
mg	Miligram

MSF	Mean stomach fullness
MVSP	Multivariate Statistical Package
N	Nitrogen
NA	Negatively allomatric
NH_3-N	Ammoniacal-nitrogen
NIS	Non-indigenous species
NO_2-N	Nitrite-nitrogen
NO_3-N	Nitrate-nitrogen
PA	Positively allomatric
PO_4-P	Ortho-phosphate
R^2	Regression coefficient
RA	Relative abundance
RGL	Relative gut length
RR	Rapid response
s	Second
SCA	Stomach content analysis
SE	Standard Error
SF	Stomach fullness
SIA	Stable isptope analysis
SL	Standard Length
SPSS	Statistical Package for Social Science
T	Temengor Reservoir
TDS	Total Dissolved Solids
TL	Total Length
TP	Trophic position
W	Weight
δ	Delta

PENILAIAN TERHADAP SPESIS IKAN BUKAN ASLI DARI TAKUNGAN TEMENGOR DAN CHENDEROH, MALAYSIA

ABSTRAK

Penilaian terhadap spesis ikan bukan asli di Takungan Temengor dan Chenderoh telah dijalankan berdasarkan data yang diperolehi dari September 2014 hingga April 2015. Perkumpulan ikan di Takungan Temengor dan Chenderoh telah dinilai. *Oreochromis niloticus* dari Temengor, *Cichla ocellaris* dari Chenderoh dan *Hampala macrolepidota* dari kedua-dua takungan ini telah dipilih untuk analisis hubungan panjang-berat dan faktor keadaan. Analisis kandungan perut dan analisis isotop stabil telah dilakukan bagi *C. ocellaris* dan *H. macrolepidota* dari Takungan Chenderoh untuk menilai pemakanan dan paras trofik. Dua puluh lapan spesis ikan yang terdiri daripada 14 famili telah direkodkan semasa kajian ini. Dua spesis ikan bukan asli telah ditemui di Takungan Temengor dan enam spesis ikan bukan asli telah direkodkan di Takungan Chenderoh. Berdasarkan nilai *b*, semua ikan yang terpilih menunjukkan corak pertumbuhan isometrik. Berdasarkan kekerapan frekuensi (%FOC), berangka (%N), perpuluhan (%P) jenis makanan, dan relatif panjang usus (RGL) ikan yang terpilih, *O. niloticus* dan *C. ocellaris* masing-masing dikategorikan sebagai piscivore dan karnivor. Berdasarkan nilai $\delta^{15}N$, *C. ocellaris* dan *H. macrolepidota* masing-masing merupakan pengguna tertier/kuaternari dan pengguna sekunder pada peringkat jaringan makanan.

AN ASSESSMENT OF NON-INDIGENOUS FISH FROM TEMENGOR AND CHENDEROH RESERVOIRS IN MALAYSIA

ABSTRACT

Assessments of non-indigenous fish (NIS) from Temengor and Chenderoh Reservoirs were conducted based on the data obtained from September 2014 to April 2015. Fish assemblages of Temengor and Chenderoh Reservoirs were assessed. *Oreochromis niloticus* from Temengor, *Cichla ocellaris* from Chenderoh, and *Hampala macrolepidota* from both reservoirs were selected for length-weight relationship (LWR), and condition factor (*Kn*). Stomach content analysis (SCA) and stable isotope analysis (SIA) were performed for *C. ocellaris* and *H. macrolepidota* from Chenderoh Reservoir to assess diet and trophic position (TP). Twenty eight fish species comprised of 14 families were recorded during this study. Two NIS fish species were found from Temengor Reservoir and six NIS fish species were recorded from Chenderoh Reservoir. Based on *b* value, all the selected fishes displayed isometric growth pattern. Based on frequency of occurrence (%FOC), numerical (%N), points (%P) of food items and relative gut length (RGL), *C. ocellaris* and *H. macrolepidota* were categorized as piscivore and carnivore, respectively. Based on $\delta^{15}N$ values, *C. ocellaris* and *H. macrolepidota* were occupying tertiary/quaternary consumer and secondary consumer level in the food web, respectively.

CHAPTER I

INTRODUCTION

1.1 Introduction

Unintentional and deliberate introduction of species to our ecosystems is a frequent phenomenon since antiquity (Di Castri, 1989; Balon, 1995; Hughes, 2003; Sultana & Hashim, 2016). Along with other frequent anthropogenic goings-on liable for the ramification of our environs, these introductions are affecting our ecology, economy, and society (Meyerson & Mooney, 2007). Ergo, for centuries, introduced as well as non-indigenous species (NIS) and invasive alien species (IAS) are recognized as archetypal ecological concerns amongst the noteworthy coercions of the global biodiversity (Pimentel *et al.*, 2000, 2005; Pejchar & Mooney, 2009).

The freshwater ecosystems all over the world are top plausible whereabouts for efficacious species introductions due to the frequency, duration and magnitude of anthropogenic influences (Gherardi, 2007; Rahel, 2007; Francis, 2012). Therefore, the global freshwater biodiversity is declining at a greater rate (Sala *et al.,* 2000) and the aforementioned are defined alarming concerning the existing and potential impacts of NIS, making them precedence for research, conservation, and sustainable management (Vorosmarty *et al.*, 2010).

Freshwater fishes are one of the absolute introduced taxa around the world (624 species: Gozlan, 2008) and this introductions and corresponding ruthlessness of influences to the ecosystems can be occurred to a countless extent. It is estimated that approximately 20% of the freshwater fish species of the world (1800 species) are already extinct or endangered due to NIS introduction (Gozlan, 2008). Therefore, fish introduction and fish invasion in freshwater ecosystems deserve adequate research, observant consideration, and most importantly, rapid respond.

1.2 Background of the study

1.2.1 Non-indigenous species (NIS) and invasive alien species (IAS)

An introduced or non-indigenous species (NIS) refers to that species, sub-species, race, variety or any lower taxon (including gametes, propagules or part of an organism) that might subsist, persist and subsequently reproduce in an innovative environment which neither occurs naturally in that particular geographical area nor ensue there before and its dispersion into that region was arbitrated directly or indirectly by human either deliberately or unintentionally (Daehler, 2001; Occhipinti-Ambrogi & Galil, 2004; Copp *et al.,* 2005; Sultana & Hashim, 2016).

Besides, an invasive alien species (IAS) is that particular introduced species whose introduction to a new geographic area does or is likely to does economic, environmental or humanoid vandalism (Sultana & Hashim, 2016). Likewise, an IAS fish can be defined to that of NIS fish, whose introduction to a new aquatic ecosystem threatens the diversity, distribution and abundance of the native biodiversity or unbalances the ecological constancy and stability of that infested water, or devastates aquacultural, agricultural, commercial, or any recreational activities dependents on aforesaid water body.

Non-indigenous species are, moreover, termed as introduced, exotic, non-native, alien, xenic, noxious, weedy, pest and foreign. However, all introduced species are not likely to become invasive. It is estimated that only 10% of introduced species will progress through each stage of invasion, which include: (1) escape and casual establishment, (2) naturalization and (3) detrimental impact/pest status (Lockwood *et al.*, 2005; Pyšek & Richardson, 2010; Larson, 2007) (see literature review for brief description).

1.2.2 Beginning of NIS fish introduction in the world

Species have been transported from their native ranges to new areas since human have voyaged over and between land masses. NIS fishes have predominantly been introduced into virgin ecosystems through human exertions since the Neolithic period (Fasham & Trumper, 2001). But the degree of introductions has vastly increased since the turn of the nineteenth century (Francis, 2012). However, the information on whys and wherefores for those species introductions are far from comprehensive, particularly before pre-19s, and the data come-at-able are often vague.

1.2.3 Beginning of NIS fish introduction in Malaysia

Malaysia underwent an extended history of NIS fish introduction which was started in this country at the beginning of 20th century, with the colonization of Southern Chinese (Mohsin & Ambak, 1983; Ali, 1998). Human colonization is one of the prime reasons of species introduction around the world (Mack & Lonsdale, 2001; Hughes *et al.*, 2003). Subsequently, after World War II, several NIS were introduced in this country by the Department of Fisheries, semi-government bodies, private sectors and individuals either intentionally or unintentionally for various objectives.

1.2.4 Fish culture and introduction of NIS tilapia in Malaysia

Even though aquaculture is considered as a longstanding tradition, modern aquaculture is fundamentally a post-1950 phenomenon in Malaysia. The perception that tilapia (*Oreochromis* spp.) would be a potential panacea to the growing animal-protein deficiency, its culture arose to terminate the reason indicated (Lin *et al.,* 1997). Consequently, *Oreochromis niloticus* became the preferred tilapia species for aquaculture in this country (Smith & Pullin, 1984). In Malaysia, freshwater cage-culture, especially tilapia culture was typically started in abandoned mining pools and reservoirs at the beginning (Rahim *et. al.,* 2013).

1.2.5 Sport-fishing and introduction of Bass fishes in Malaysia

Recreational fishing or sport-fishing is correspondingly a weighty reason for the introduction and establishment of NIS fish species in Malaysia (Rahim *et al.,* 2013). Reviewing literatures on recreational fishing history of Malaysia, it is acknowledged that four NIS fish species has been introduced in this country for sport fishing and all of them are bass fishes (which are locally called as ikan raja), such as *Cichla ocellaris* (butterfly peacock bass), *C. monoculus* (peacock bass), *C. kelberi* (peacock bass) and *Micropterus salmoides* (largemouth bass) (Rahim *et al.,* 2013). As one prominent case, the peacock bass or *C. ocellaris* was deliberately introduced into a lake, made from a former mining area, in the Northern part of Perak state of Malaysia, by some reckless anglers in the early 1900 for entertainment fisheries (Khairul Adha, 2009). At present this fish can be found not only in that ex-mining lake but also in other artificial lakes and reservoirs in the middle and Southern parts of Peninsular Malaysia (Khairul Adha, 2012).

1.2.6 Introduction of tilapia in Temengor Reservoir

Culture of tilapias in Malaysia has gone through a number of developmental phases since the nineteenth century. As a part of this development, cage cultures of tilapia become established in the reservoirs and natural water resources of Malaysia to assure the responsible use of resources, fish health and welfare, and conservation of biodiversity. For instance, Trapia Malaysia Sdn. Bhd. has started a state-of-art commercial cage farm for tilapia in Temengor Reservoir. The farm was set up 8 years ago, in 2008, as an eco-friendly aquaculture facility and operates within an industrial aquaculture zone in Temengor Lake, Perak (fishconsult.org; visited in 5th April, 2016). The farm has its own hatchery in Bongor, Grik which produces Nile tilapia fries (*O. niloticus*) for this cage-culture purpose. Therefore, the tilapia species which is used for aquaculture in Temengor are mostly *O. niloticus* (fishconsult.org; visited in 5th April, 2016).

1.2.7 Introduction of Bass fishes in Chenderoh Reservoir

In Chenderoh Reservoir, bass fishes (*Cichla ocellaris* and *Cichla keberi*) were introduced by the Department of Fisheries, Malaysia, mainly for the sport-fishing or entertainment purposes. However, the time and magnitude of these introductions are unknown (Rahim *et al.*, 2013).

1.3 Justification of the study

1.3.1 Possible impacts of NIS fishes in freshwater ecosystems

Potential impacts of an invasive fish in the introduced ecosystem know no bounds. Therefore, impacts of NIS fishes are being studied watchfully and repeatedly worldwide. Some widely inspected effects of NIS fish in some freshwater ecosystems of the world include 1) modification in gene transcription patterns; 2) hybridization and introgression; 3) modification in bio-chemical cycles of the ecosystem; 4) modification in trophic positioning system in the food web and so on (Table 1.1).

1.3.2 Preliminary assessments on introduced species

Preliminary assessment is termed as "early detection" (ED) in invasion biology which conjointly and frequently used with the term "rapid respond" (RR). Preliminary assessment as well as early detection increases the likelihood that invasions in a particular area/ecosystem can be addressed (control or eradication efforts) successfully before the population of the invasive species are still localized (Anderson, 2005). Therefore, early detection is stated as a necessary effort for every ecosystem which is suspected to be invaded by any kind of introduced species because once the populations of introduced species are widely established or become invasive, the mitigation of negative impacts is quite challenging (Simberloff, 2003). In addition, the costs associated with the efforts are typically far less than those of long-term invasive species management programs (Vander-Zanden *et al.*, 2010).

Table 1.1: Possible effects of NIS which may function athwart multiple levels of an ecosystem.

Level of effects	**Type of effects**	**Reference(s)**
Genetic level	Modification in gene transcription patterns	Roberge *et al.* (2008)
	Hybridization and introgression	Rhymer and Simberloff (1996), Allendorf *et al.* (2001), Streelman *et al.* (2004)
Individual level	Behavioral vagaries	Rogers *et al.* (2008), Blanchet *et al.* (2008)
	Morphological deviations	Bourke *et al.* (1999), Mooney and Cleland (2001), Fisk *et al.* (2007)
	Sways on vital rates	Segev *et al.* (2009)
Population level	Transmission of parasites	Hoffman *et al.* (1984), Krueger and May (1991), Prenter *et al.*(2004)
	Competitive tactic	Taniguchi *et al.*(2002), Ruetz *et al.* (2003), Baxter *et al.* (2004), Olsen and Belk (2005), Kadye and Magadza (2008), Penaluna *et al.* (2009)
	Distributional effects	Gratwicke and Marshall (2001), Korsu *et al.* (2007), Alcaraz *et al.* (2008)
Community level	Species extinction	Didham *et al.* (2005), Gherardi (2007), Mandrak and Cudmore (2010)
	Homogenization of species	Leprieur *et al.* (2008), Rahel (2002)
Ecosystem level	Habitat alteration	Leslie and Spotila (2001), Koehn (2004), Pipalova (2006)
	Modification of bio-chemical cycles	Schindler (2001), Starling *et al.* (2002), Eby *et al.* (2006)
	Modification of trophic interaction	Carlsson *et al.* (2004), Britton *et al.* (2010), Dawe *et al.* (2012)
	Effects on ecosystem resilience	Holling (1996), Pyšek and Richardson (2010)

1.3.3 Problem statement

In the area of Tasik Banding, Temengor, there are anecdotes amongst the natives that tilapia has been frequently caught and observed throughout Belum-Temengor Reservoir. It is predicted that the species somehow succeeded to escape from the integrated cage culture zone and thereby reproduce in the wild. However, there is no evidence/study report/information yet to prove the rumors. Therefore, this study was a milestone to prove the reality. Moreover, the present status (such as abundance, wellbeing, diet and condition) of the escaped tilapia in the wild was focused to explore in this research.

Besides, the intentional introduction of bass fishes has traditionally been viewed as a form of fishery enhancement in Chenderoh Reservoir and, until now, there has been a little concern about their ecological consequences. Therefore, this study was a pioneer which explores the preliminary conditions and facts of the invasive bass species in Chenderoh Reservoir.

1.4 Limitations of the proposed research

1.4.1 Using passive gear (gill-nets)

In this study, passive gear gillnets were used to catch fish from the reservoirs. Although there are benefits of using gillnets, such as it can be set at different depths (Portt *et al.,* 2006) and samples can be taken continuously over a long time period, they are strongly species selective and biased towards more active fish species. Besides, there is a very high rate of mortality and injury for fish caught in gill nets. Moreover, it required a return trip to retrieve gears, which raised the level of resources required to collect data, particularly in remote areas.

1.4.2 Not considering comprehensive analysis

In this study, the spatial and temporal distribution of fish was excluded and seasonal influences on fish assemblage were not considered as an analytical implement, since it is a preliminar assessment study. Moreover, for stomach content analysis, fishes of only a specific size range were considered due to limitation of time and budget. Therefore, this study is unable to explain the size related and seasonal variation in food items taken by the fish species. Besides, for stable isotope analysis, only the adult individuals were measured due to limited budget. So, it fails to provide the relative trophic positioning of fingerling or juvenile fishes which may vary in a specific species within size classes.

1.4.3 Using dead fish for stomach content analysis

Since gill nets were used to capture fish, most of the specimens were dead by the time of retrieved. Stomachs from the dead fishes were used to analyze the contents which could bias the result, since diets start to break down as the fish dies. However, digestion rate for all diet are not same. Therefore, to minimize this bias, both guts (foregut and hindgut) were included for content observation. However, considering both gut for analysis created problem in counting diet for omnivore species (such as tilapia) which mostly consume phytoplankton.

1.5 Research objectives

The goal of this study was to detect non-indigenous (NIS) fish in Temengor and Chenderoh Reservoir and preliminary assessments on the NIS fishes to understand the present status and the likelihood of their invasion potential. Therefore, this study ended up with three objectives:

1. To determine fish assemblage of Temengor and Chenderoh Reservoir.
2. To determine length weight relationship (LWR) and condition factor (*Kn*) of selected IS and NIS fish species from Temengor and Chenderoh Reservoir.
3. To identify diet and trophic position (TP) of selected IS and NIS fish from Temengor and Chenderoh Reservoir through stomach content analysis (SCA) and stable isotope analysis (SIA).

CHAPTER II

LITERATURE REVIEW

2.1 Perspectives about NIS and IAS by scientists

In the last few decades, NIS and IAS have been treated by scientists as "species out of place"/ "pollutant": the organisms that do not belong in their current environment (Van Driesche & Van Driesche, 2004; Francis, 2012). With the growing awareness of the potential threats posed by these introduced species, this perception has generated widespread grounds for apprehension (Brown & Sax, 2004; Stromberg *et al.*, 2009). Therefore, lately, the research queries, information database and the scientific objectives that help understanding such species were intensively focused by the ecologists (Stromberg *et al.*, 2009; Lavoie, 2010).

2.2 Steps and stages of NIS to IAS

NIS fish are requisite to pass a number of topographical and ecological hindrances to turn out to be invasive. Partition of the invasion process into steps and stages or transitions (Kollar & Lodge, 2001) gives us a better understanding of biological invasion (Heger *et al.*, 2001; Heger & Trepl, 2003; Williamson, 2006). Furthermore, if the invasion process is divided, different approaches can be used to explain the success/failure in different invasion steps. It is estimated though, only a minor portion (~10%) of introduced species will progress through each stage (Williamson & Brown, 1986; Williamson & Fitter, 1996; Pyšek & Richardson, 2006; Ricciardi & Kipp, 2008).

2.2.1 Introduction and establishment phase

Introduction phase is the initial phase of a NIS, by which they elect from a donor area, conveyed to a recipient area, and anywise released into an aquatic atmosphere (Figure 2.1). NIS can be introduced either intentionally or unintentionally (Larson, 2007) to the new region.

This is the phase whereby an introduced species reproduces and forms self-sustaining populations without relying on further introduction (Williamson & Fitter, 1996; Larson, 2007). Introduced species, which have the potentiality to withstand and reproduce in new surroundings, is likely to pass through the establishment phase (Figure 2.1). Moreover, NIS from an area with similar circumstances as recipient area increases the odds of subsistence (Baker, 1974). Propagule pressure (*i.e.*, the size of each releasing event and the number of releases) is also an important factor for establishment success of introduced species (Lockwood *et al.*, 2005; Pyšek & Richardson, 2010; Larson, 2007).

2.2.2 Invasion phase

In this phase, it's obligatory for the species to upsurge in quantity and thereafter spread. The spread can either be vector mediated or natural, and is often a convoluted process (Hastings *et al.*, 2005) (Figure 2.1). Nevertheless, spreading from introduction area is crucial to become invasive, because the ability to banquet substantially stimulus the ultimate size of the IAS population and their potential of invasion (Simberloff *et al.*, 1998).

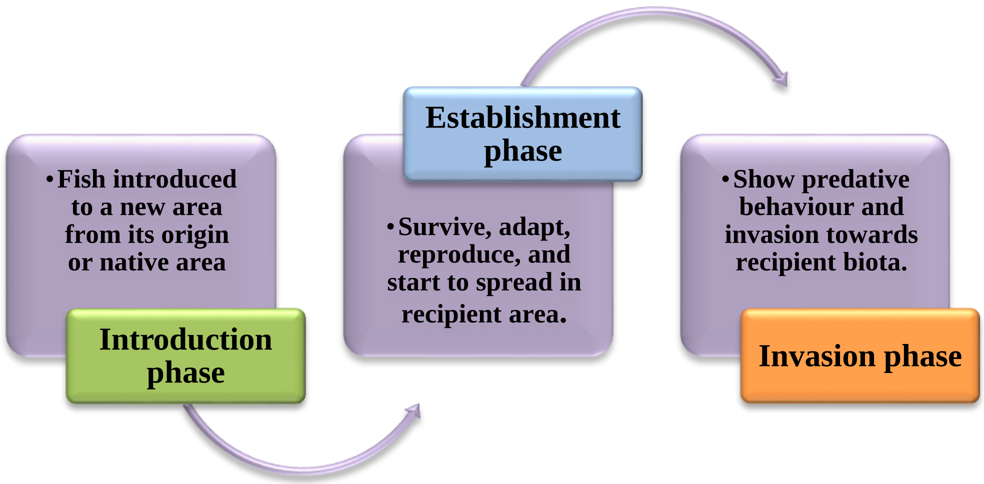

Figure 2.1: Schematic illustration showing process of biological invasion [modified from Larson (2007)].

2.3 Fish assemblage

Fish assemblage combines the species richness, diversity, morphological and physiological attributes and trophic structure (Zarul Hashim, 2006). Studies on the fish assemblage in reservoirs in the same river basin are essential to understand the functioning of the river as well as the reservoirs. The approach and techniques to analyze fish assemblage in community level depends on the objective of the study (Kwak & Peterson, 2007). Therefore, to accomplish fish assemblage, fish checklist, species composition, relative abundance of IS and NIS species, family's composition, fish diversity and evenness and species rarity are worth discussed (Krebs, 1998; Southwood & Henderson, 2000; Kwak & Peterson, 2007).

2.3.1 Fish assemblage of Temengor and Chenderoh Reservoir

Previous studies on fish assemblage of Temengor Reservoir (lotic and lentic) include Zakaria-Ismail and Lim (1995), Zakaria-Ismail and Sabariah (1994), Mohd-Akhir (1999), Berryhill-Jr. (2003), Hashim *et al.* (2012), Hamid *et al.* (2012), Kaviarasu *et al.* (2013), Ismail *et al.* (2013), Mohd-Shafiq *et al.* (2013) and Amirrudin and Zakaria-Ismail (2015). Amiruddin and Zakaria-Ismail (2015) reported that 42 fish species were found in the reservoir and streams that flow into Temengor Reservoir, whereas Zakaria-Ismail and Lim (1995) found only 23 species.

Previous studies on fish assemblage of Chenderoh Reservoir include Ali and Lee (1995), Ali (1996), Ali (1998), Kah-wai and Ali (2000), Khairul Adha (2012), and Rahim *et al.* (2013), where they mentioned about the introduced fishes of this reservoir and their probable consequences to the native fish community and the habitat.

2.4 Probable reasons of vulnerability of NIS fish invasion in Chenderoh

2.4.1 Landscape position / location of the reservoir

Chenderoh Reservoir is located in landscape areas of low elevation, after three reservoirs (Temengor, Bersia and Kenering) and before the Bagan Datoh estuary. Therefore it embodies ‘sinks’ for a wide variety of materials, including water, sediment, nutrients, propagules and pollutants (Zedler & Kercher, 2004). Zedler and Kercher (2004) have argued that this ‘sink’ function increases wetland invasibility. They also noted that reservoirs without surface runoff (such as high altitude fens and bogs) have lower numbers of NIS species. Certainly, the reception and storage of these materials in reservoir helps to create a favorable condition for the NIS fish to become invader. Besides, high nutrient flux and sediment delivery helps the NIS to maximize their performance and compete with the natives. However, besides the landscape position, high propagules pressure is also a key associated factor in invasion success of a NIS fish (Lockwood *et al.,* 2005). Nevertheless, addition of biotic and abiotic materials to the reservoir water can be further exacerbated by anthropogenic activity, which can facilitate the invasion success, for example increased nutrient input into reservoir via the use of fertilizers within the catchment areas, or increase sediment entrainment due to soil erosion can help the NIS to predate over native population (Richardson *et al.,* 2007). Anthropogenic activities (*e.g.,* agriculture) at the catchment areas of Chenderoh Reservoir were observed during sampling excursion, which is predicted to smooth and promote the predation and invasion process of *C. ocellaris* over an uncertain period.

2.4.2 Anthropogenic activities / modifications within and around

Anthropogenic activities both within and around freshwater ecosystems can directly increase the invasibility (invasion potential) of a NIS fish (Ervin *et al.,* 2006; Richardson *et al.*, 2007). The most dramatic impacts on freshwater systems are related with flow regulation, which include shard engineering such as the construction of dams and reservoirs (Francis, 2012). Such modifications influence both connectivity and disturbance of the water and greatly affect the invasion procedure. Flow regulation reduces the duration, intensity and extent of high water events, which can result in native communities losing their adaptive advantages and increasing the probability of successful NIS establishment (Hobbs & Huenneke, 1992; Predick & Turner, 2008). The consequences also reflect in water level downstream of dams, reduction of channel width, exposure of sediments and lower inundation stresses which ultimately changes the community composition, supports the establishment of NIS fish and increases the NIS fish abundance (Richardson *et al.,* 2007).

2.4.3 Water flow regime of Chenderoh Reservoir

The flow regime of a water body determines the frequency, duration and intensity of many forms of disturbance, which are responsible for both the creation and destruction of aquatic habitat. For example, establishment of dams and reservoirs (Gregory *et al.,* 1991; Stanford *et al.,* 2005), transportation and deposition of biotic and abiotic ecosystem components can alter the flow. Disturbance can relate to both increases and decreases in flow, and can be both beneficial and detrimental to the spread and establishment of alien species (Richardson *et al.,* 2007). The flow and water level regime of Chenderoh Reservoir is largely affected by the releases from the upstream reservoirs; Kenering Reservoir (1984), Bersia Reservoir (1993) and Temengor Reservoir (1974) (Dahlen, 1993). Therefore, being the last positioned reservoir, water-level management and retention time of this reservoir is highly dependent on the water management schemes of the three upper reservoirs and thereby disturbed through the transportation and deposition of biotic and abiotic sedimentation.

If a species has a greater capacity to tolerate or recover from disturbance then it may be able to outcompetes natives and become dominant. Some NIS fish demonstrate increased tolerance to stresses associated with fluvial disturbance such as high flow velocities, inundation, suspended sediments or burial and displays greater invasive potential in the ecosystem (Tickner *et al.,* 2001; Zardi *et al.,* 2006). For example, bass fishes such as *C. ocellaris* have a greater capacity to tolerate disturbance and therefore can adapt in any disturbed ecosystem it introduced. Other similar species are alien crayfish *Orconectes neglectus* and *Pacifastacus leniusculus* (signal crayfish), who demonstrate high tolerances to disturbed water (Larson, 2007). Therefore, the possibility of *C. ocellaris* establishment in this reservoir is comparatively high. However, sometimes in contrast, natural disturbance regimes of a water body may help to prevent the spread and establishment of NIS species. For example, those NIS fish that are dominative but not able to adapt with a particular hydro-geomorphic stress, cannot compete with native species. Fausch *et al.* (2001) found that the invasion success of such fish *Oncorhynchus mykiss* (rainbow trout) was higher in reservoirs where the flow regime is low.

2.5 Identifying invasion / predation potential of NIS fish

Estimating and exact pronouncement in foretelling the invasion potential of an introduced fish species in an ecosystem is a challenging task (Byers, 2002). Largely because, every system goes through the adjusting influences of local surroundings, customs, cultures, atmospheres, and heritage. Furthermore, very few general hypotheses have been fabricated to compute actual extent of predation (Francis, 2012). Consequently, predictive models or generalized forecasting methods of impact by invader fishes are almost nonexistence (Ricciardi, 2003). However, by congregating and analyzing some preliminary information, facts and figures we can foresee whether predation by a particular NIS fish on native population is obvious or not. These tasks are basically known as early detection and preliminary assessments.

2.5.1 A new survey or periodical monitoring

A new survey or periodical monitoring of an ecosystem is the basic effort to confirm the presence/absence of species introduction. Determining fish assemblage in a predicted ecosystem could be the fundamental exertion in this regard. Thus, it is easier to identify the existence and distribution of NIS fish including native ones (Williamson & Fitter, 1996). Besides, a follow-up data or updated information of the ecosystem could also be gain which would help to take further factual initiatives for that particular ecosystem (Figure 2.2). By determining fish assemblage (*i.e.*, diversity, distribution, and relative abundance) a preliminary idea of the NIS fish composition in that ecosystem could be accredited which is ecologically known as early detection.

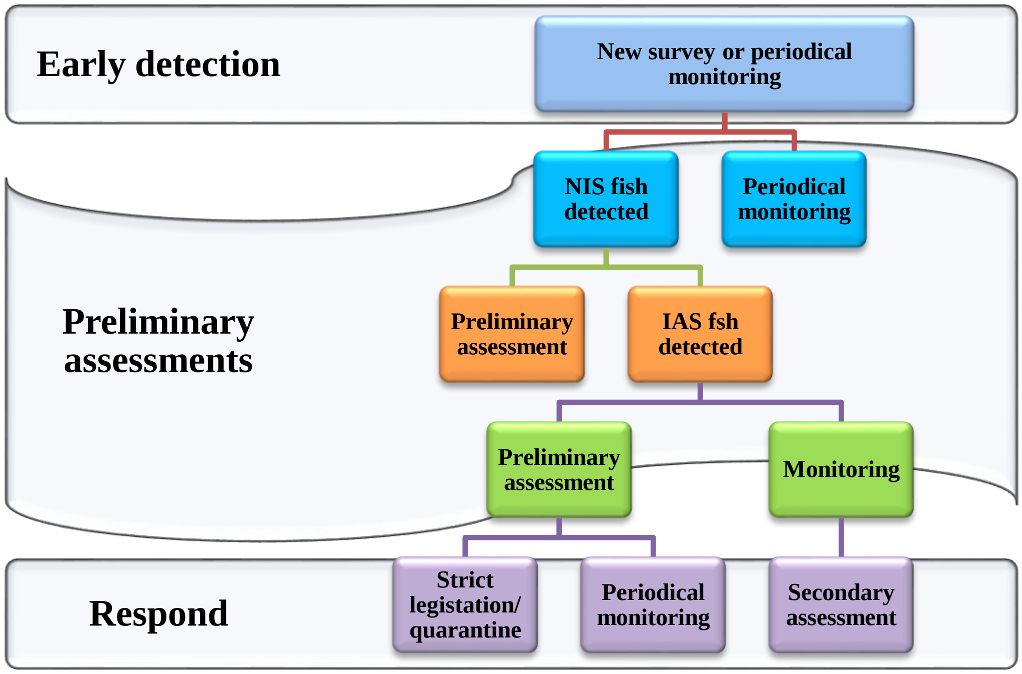

Figure 2.2: Early detection and preliminary assessments on introduced species with a new survey and periodical monitoring [figure modified from Wittenberg & Cock (2001), Genovesi & Shine (2004)].

2.5.2 Assessments on length-weight relationship and condition factor

Measures of condition are generally an indicator of tissue energy reserves of fishes, which may answer and characterize several environmental components (*e.g.*, habitat and prey availability) in which the fish belongs to. Moreover, distinguishing the condition factor of NIS fish in an ecosystem can provide insights of establishment of the species, either the species is being capable to subsist in the new environment or not (Kolar & Lodge, 2001; Pope & Kruse, 2007). Thus, this could be a preliminary investigation of the status of NIS fish in any ecosystem. Furthermore, analyzing and comparing the condition of NIS and IS population of a predicted ecosystem (prediction of invasion) can be an approach to foresee the predation of introduced species over native population (Brown & Murphy, 1991; Ruiz *et al.,* 2000; Nehemia *et al.,* 2012).

2.5.3 Stomach content analysis (SCA) of fish

Diet assessments are an integral part of fish ecology researches which is widely used as an important means of investigating trophic relationship and predatory as well as invasion symptoms of NIS fish in the aquatic communities (Fagbenro *et al.,* 2000; Chipps & Garvey, 2007). Diet of fishes represents an integration of many ecological components including behavior, condition, habitat use, energy intake, and inter-and-intra-specific interactions. Therefore, stomach content analysis of fish can response to a variety of research objectives including foraging trade-offs associated with predatory symptoms in a community. Moreover, since fish have a wide range of diet and feeding habits (*e. g.,* herbivorous, carnivorous) and have diverse trophic niche, information on diet of fishes facilitates better understanding of their feeding adaptation, invasion potential, predatory symptoms, predation scope on other species, and other associated and interrelated biological aspects (Fagbenro *et al.,* 2000; Ogbe *et al.,* 2008). Hence, stomach content analysis and categorization of fish from their observed diet is a must do effort of primary assessment on NIS fish in an ecosystem, because all categories of fishes are not likely to invade or predate the community.

Primary diet analysis measures, commonly used to predict invasion potential of NIS fish, includes 1) categorization of fish according to relative gut length; 2) assess and compare trophic positioning of fish with similar diet; 3) assess and compare relative importance of diet of fish with similar diet; and 4) relative impact of NIS fish on IS fish by comparing foraging activities (Chipps & Garvey, 2007) (Figure 2.3).

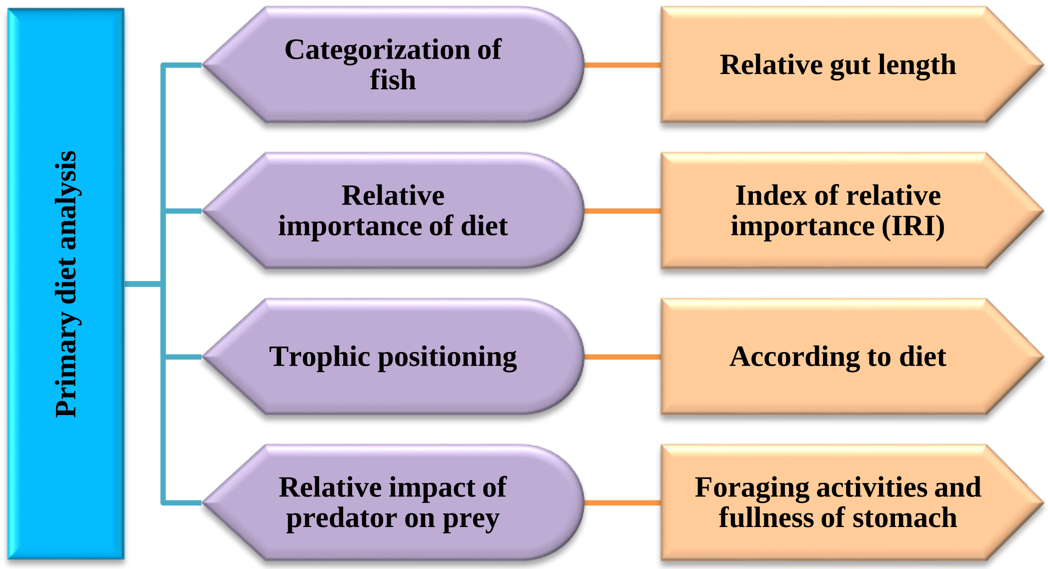

Figure 2.3: Primary diet analysis measures, commonly used to predict invasion potential of NIS fish. Chart modified from Chipps & Garvey (2007).